

SPECIAL COMMUNICATION

Reflections on the saga of tar content: why did we measure the wrong thing?

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Introduction

In 1999, it seems timely to reflect on the beginnings of the campaign to reduce tar and nicotine content of cigarettes, and on the mistakes made over the past three decades.

As a persistent and experienced critic of the tobacco industry I am nevertheless surprised to find, in 1999, that they have exceeded my more pessimistic expectations, with what can only be described as a foolishly casual approach to addressing the carcinogenic content of the smoke they feed their customers, combined with an efficient and intense focus on the addictive elements.

In 1968 I became director of the Anti-Cancer Council of Victoria (ACCV), Australia. My predecessor had commissioned a US analysis of the tar content of 10 randomly selected Australian brands of cigarettes by Fred Bock. I recall that we were not asked to pay for the tests, which were a simple fishing expedition.

The tar content of the sample ranged from 17-33 mg per cigarette and David Hill, then director of education in the ACCV, published this in our newsletter, *Victorian Cancer News*, under a headline "Victorian cigarettes a case of Russian roulette". The responses were instantaneous.

The first were major headlines in Australian newspapers, attacks from various tobacco industry sources, and a consequential controversy, with us arguing that the levels were too high and wanting them brought down and printed on the packet.

The second was a very large increase in the sales of *Kent* which happened to have the lowest tar of the brands we had tested (17 mg). This experience persuaded us to set up our own testing to explore the whole market, as only the Americans were publishing this material at this time.

We commissioned Professor John Swan, a distinguished organic chemist, to organise the testing of all Australian brands, which was easily done with a little ingenuity. His engineer, Ben Baxter, designed and built a machine similar to that used by Fred Bock. The principle was extremely simple. Twelve ports were set up in which cigarettes were smoked by applying a standard vacuum for a standard period to produce a puff volume of 35 ml. The smoke was then channelled through a narrowed outlet through a filter paper of consistent manufacture. The particulate

matter, which was captured by the filter, was weighed.

An excited John Swan phoned me a few months later. The honours student doing the tests had found a discrepancy within a single brand—Hallmark. The single port results were showing variable results, an unusual thing. Swan had purchased a carefully designed national sample. Hallmark purchased in New South Wales was delivering a consistent 14 mg, while those purchased in Victoria delivered a consistent 7 mg.

Clearly we had happened upon a marketing experiment in which the industry was test marketing a lower tar version of the brand to discover whether their customers could tell the difference. We had seriously disturbed their experiment and our published results produced a publicity storm, which reportedly expanded sales by some orders of magnitude. The demand caught them short of filters so a planeload was flown out from England, amid continuing publicity. In the absence of detailed industry figures we could only assume that Hallmark had stolen market share from higher tar brands, and we were pleased with the very widespread publicity which allowed us to focus on the dangers of higher tar cigarettes. Our policy response was to "measure, publish, debate" which we did, on and off, for another two to three decades.

By the mid 1980s, 80% of Australian brands delivered 12 mg of tar or less.¹ In 1991 half of Victorian smokers could recount the tar content of the cigarette they smoked. In the context of the times this was seen as progress.

In the early 1970s, being young in the job, I was willing, at least until I learned better, to talk to a couple of people the industry sent around to see me without a third party present. The first was an old footballing friend, recently hired but well briefed, who explained to me the industry's "positions" on various subjects. It was at this time in my life that I discovered that a "position" is not the same as a fact. Phrases like "It's only statistical" and 20 or 30 other industry euphemisms became familiar to me. My friend did not enjoy his job as his employer's "positions" were different from my facts and he found himself believing me. He left the industry not long after. However, he did me the favour of sending around one of their senior biochemists, who educated me considerably.

After we put aside discussion about whether cigarettes caused lung cancer, on which I was

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obdurate and he was elegantly obfuscatory and non-committal, we had some useful dialogue about tar content. Reducing tar could be done by filtration, by choice of tobacco and paper, by blending, by use of reconstituted leaf, and various other means. Ventilated filters, which artificially reduce machine yields, were unknown in those days. Adding burning agents made the cigarette keep burning when not being puffed, which reduced puff count and what reached smokers' lungs, but increased what went elsewhere. A high tar cigarette in those days (the Philip Morris brand in Australia was 32 mg) delivered 9–10 puffs; a low tar brand delivered 7–8 mg. We were both aware of Ernst Wynder's experiments in painting mouse skin with tobacco tar, and of the dose-response between the amount applied and the yield of tumours.^{2,3}

My approach at the time was simple and not particularly intellectual. It seemed to me that if smoke with lots of particles produced lots of cancer, as it clearly did, then smoke with a large proportion of particles removed had a good chance of being significantly less carcinogenic.

This reasoning should have been correct. It did not occur to me then that the industry would be silly enough to actually increase the amount of carcinogen within the smaller number of particles, although, as shown later, it seems that this is what they have done. Their biochemist actually mentioned it as a possibility, but we both dismissed it on the grounds that it would be preposterous.

There were some hilarious moments in these discussions. I remember bursting into laughter when he used the words "quality control" but he did make it clear to me that they were trying, for obvious reasons, to produce a consistent product.

These were the early 1970s and the debate was to become much more intense as time went on. The industry trick of discussing a "safer" cigarette failed in Australia as we countered, vigorously, with phrases like "more dangerous". By and large the civilities were observed on both sides at that time. I probably breached the code, and personalised the issue for the first time, when the chairman of a tobacco company was given a knighthood in the early 1970s, by pointing out that "You get a knighthood for pushing cigarettes but a gaol sentence for pushing marihuana". A number of senior people on my side of the fence deprecated this. However, there were no more tobacco knighthoods in Australia. These were certainly trying times for the tobacco industry. A pleasant habit had been revealed as seriously dangerous and, in due course, addictive; and a then respectable industry came under progressive and increasing attack, which has continued and is now focused in the courts of the United States.

Over the next decade I had many debates with my public health friends over tar. They were rightly concerned about the concept of the "safer cigarette" which was propagated by the industry and compliant journalists in countries where they were allowed to get away with it. For this reason the Union International

Contre le Cancer (UICC) monograph on tobacco policy of 1977⁴ promoted reduction by regulation rather than by the industry responding to market demand. In Australia we continued our policy as before, as the debate was useful in keeping the issue of the (unnecessarily) dangerous cigarette in the public arena.

The 1980s and on

In the mid 1980s the International Agency for Research on Cancer (IARC) convened a working party, in which I participated, to write a monograph on tobacco smoking.⁵ The group reviewed six epidemiological studies^{6–11} concluding "The low tar cigarette appears to reduce the risk for lung cancer". This fitted my conceptions of the time. I also took notice of what the chemists in that working party were saying. They noted the carcinogenicity of the tobacco specific nitrosamines (TSNA) in particular N'-nitrosornicotine (NNN) and 4-(methylnitrosamino)-1-(3-pyridyl)-4-butanone (NNK), and the relation between these and the amount of nitrate in tobacco.¹²

Other publications in the 1980s supported the satisfying view that reducing tar reduced lung cancer^{13–15}; certainly the mortality from this disease was declining in males in some countries, with this decline being attributed to both reduction in cigarette consumption and reduction in quantitative tar yields.¹⁶ Governments, and some in the public health community, supported voluntary agreements aimed at tar and nicotine reduction. In the UK there existed a "product modification programme"¹⁷ and in Canada a voluntary agreement.¹⁸

Nicotine posed a very different problem to tar. I probably learned about addiction from reading Michael Russell in the 1970s¹⁹ and certainly learnt about compensatory smoking in the same decade from the same source²⁰ and others.²¹ Nevertheless I went along with the prevailing opinion that reducing tar, which incidentally reduced nicotine (or so I believed at the time), was sound policy. Russell in 1976²² proposed a cigarette with limited tar (6 mg) and "adequate" nicotine (1–1.2 mg) but few took much notice. The main objection then to the low tar cigarette was the possibility that it could serve as an alternative to quitting, a proposition the industry exploited with the development of Lights, Milds, and Ultra Lights.

In the late 1980s it became apparent that there were straws in the wind suggesting that all was not well with the low tar/nicotine policy.

The straws

There were four areas to be concerned about. As the evidence has unfolded in the 1990s these concerns have become serious.

Hoffmann²³ progressively published data which showed an increase over time in the NNK yield of a single non-filter brand in the United States, of about 45%, occurring over a period when benz(a)pyrene (BaP) was stable. He also noted an increase in nitrate levels in US tobaccos. Others^{24,25} recorded great diversity in nitrosamine yields in cigarettes from different countries. So there were great

qualitative differences between cigarettes in this respect, which should logically mean that some cigarettes were more carcinogenic than others. This was unnecessary, as the nitrate content of the tobacco, plus the curing and storage processes used, is under the control of the manufacturer.

The swing towards adenocarcinoma became obvious at least in some countries.²⁶⁻³⁶ Wynder and Hoffmann³⁷ considered this to be a consequence of the higher nitrosamines in smoke and the greater exposure of the lungs to smoke particles, especially NNK, caused by compensatory smoking.

The reviews of cancer prevention study No. 1, 1959 through 1965 (CPS1) and CPS2 (1982 through 1988) showed an increase in mortality among long duration (40-49 years), one pack or more per day smokers,³⁸ whose experience includes significant periods of use of lower tar cigarettes. It was concluded that "the potential benefits of reduced tar, as measured by machine smoking, appear to be overwhelmed by adverse changes in smoking practices and perhaps by other unidentified factors".

It became increasingly obvious that industry manipulation of nicotine bioavailability in cigarettes is ensuring that modern cigarettes are as addictive as ever, or more so. I knew that nicotine levels could be easily controlled, as the industry chemist had told me so in the 1970s. I was also told by John Swan in the late 1980s about protonated and unprotonated nicotine, and its relation to pH, in the context of the smoking/chewing usage in India, but only understood that the modern cigarette was progressively delivering more unprotonated ("free") nicotine when the industry documents started to leak through the court system in the United States. I was certainly startled to discover that Marlboro had been using ammonia technology since 1965³⁹ and that their competitors knew it and copied the practice.

Conclusion

It is relatively easy with hindsight to put these four issues side by side and conclude that the modern cigarette is not an improvement and may be about as carcinogenic as its predecessor, although in a slightly different way. It also seems that it is at least as addictive as its predecessor, or more so, despite numerically lower levels of nicotine. The low tar/low nicotine policy has been, at best, a slight success; at worst, a snare and a delusion.

In this *mea culpa* I am, or should not be, alone. The public health establishments which advised governments committed the same mistakes and we have all been enlightened by the revelations brought forth by the US courts, which have confirmed that the tobacco industry always had clear policy intentions and that the making of a less addictive, less dangerous cigarette was not among them.

Although the social and legislative elements of tobacco policy have been clear, accepted and progressively implemented, at least in developed countries, for several decades, we

have shied away from attempting to regulate the product. There are at least two reasons for this.

The first is that, as I discovered when I raised this with the poisons committee in Victoria in the late 1970s, no sensible bureaucrat wants to legitimise something as toxic as a cigarette by taking responsibility for "approving" or even "permitting" it. I accepted this then as a reasonable view.

The second is that the problem is extremely complex and the "horse has bolted" to the extent that the unregulated cigarette is ubiquitous, loaded with additives, and manufactured in diverse environments. Taking control of the cigarette through regulation, as has been done with nicotine replacement products, seems difficult at a technical level regardless of the political problems.

This inactivity can no longer be condoned and our lobbying endeavours need to be directed with more clarity at bringing the cigarette under regulatory control. There are two problems. One is political, the other technical. Neither is insuperable. Regulation is unlikely to start as a global process and a number of national and supra national governments are candidates for leadership. They are the US, Canada, the European Union, and Australia and New Zealand.

POLITICAL ISSUES

In the US the question of regulation by the Food and Drug Administration (FDA) is before the courts and is likely to be resolved in the year 2000. If the US government fails, then the matter becomes one for the currently constipated, tobacco industry friendly, US Congress. However the tobacco industry is not yet finished with the jury system in the US and the loss of further court cases may well bring them back to Congress wanting another settlement, or release from liability, of the sort which was lost by divisions in the public health community in 1998.

In Europe, there is a new European Commission and the 1996 recommendations of the European high level cancer experts committee⁴⁰ are before it. These lay a base for regulation of tar and nicotine as well as for the abolition of additives. This base depends on tar and nicotine as no other measuring system currently exists, but the future must surely hold regulation of individual smoke components, as the concept of tar as a homogeneous substance is now out of date. Lowering tar beyond what is currently proposed cannot be expected to deliver benefits. Ireland already has legislation requiring disclosure and facilitating regulation.

The New Zealand government has already taken powers to regulate cigarette design and Australia has a strong legislative base for tobacco control. Canada is in a similar position.

Several individual US states and Canadian provinces (Massachusetts and British Columbia, among others) are requiring major disclosure of smoke constituents, and seem likely to

move toward regulation as a natural progression.

The technical issues in regulation are not as complicated as they might seem. Abolition of additives has already been proposed to the European Commission.⁴⁰ This is well within the industry's capacity, given two to three years to comply. Over that time, any additives which may be beneficial to public health can then be considered in the same way as they would be for nicotine replacement products—carefully, one by one, and on the basis of not only toxicology but also the effects on the addictive and carcinogenic/toxic effects of the cigarette, with the onus of proof resting with the manufacturer. Additives need to be clearly defined, as anything added anywhere in the growing and manufacturing process, from nitrate fertiliser to citrates in the paper. The “quickfix” and easy to learn to smoke cigarette with its sugars, flavourings, ammonia, and other additives, and particularly its high nicotine “kick”, would be replaced by the old fashioned “gasper”. However, the gasper would have some limits set.

Although the industry will protest against a prohibition of additives, the failures of the voluntary codes are serious. In the UK, some 600 additives are disclosed. They include a number of ammonium salts and various sugars. Ammonia increases free nicotine. Sugars, when burnt, yield acetaldehyde which is synergistic with nicotine⁴¹ but is also a carcinogen.²³ Sugar may be suitable as an additive for tea, but, since it leads to acetaldehyde when burnt, is hardly suitable for a cigarette.

Carcinogens need to be regulated by the setting of upper limits, as has been proposed,⁴² based on what levels are actually on the market and starting with the median as an initial upper limit. The starting points could be: BaP, as a surrogate for other polyaromatic hydrocarbons; NNK, as a surrogate for TSNA; and the various inorganic compounds such as heavy metals. This is not a matter of telling the tobacco industry how to manufacture a cigarette, but simply to set limits on the emissions produced by what they market. Tar measurement should be replaced by measurement of a prescribed set of nominated carcinogens.

The question of nicotine regulation becomes simpler once additives which can influence pH and bioavailability are removed. Regulation may require setting limits on the amount of nicotine permitted in the rod of the cigarette and, perhaps, limits on smoke pH. Alternatively, regulation based on levels in mainstream smoke produced by a more realistic smoking pattern may be suitable. The debate over whether to reduce nicotine levels progressively over time⁴³ needs to be resolved, but the more immediate issue is the necessity of establishing a regulatory system.

Will this make a less dangerous cigarette? Certainly a cigarette with less addictive power and lower carcinogen levels should be less dangerous, although it will never be safe or acceptable in the long term. While there is no excuse for allowing unnecessarily high levels of

carcinogens in cigarettes, there is, similarly, no excuse for allowing marketing claims as to safety to be based on reduction, but not elimination, of carcinogens. Misleading concepts such as light and mild, simply have no place. The future of the product, if it has one, may lie in the evolution of less objectionable alternative forms of nicotine delivery which bring fewer, or no, carcinogens and toxins in their wake.

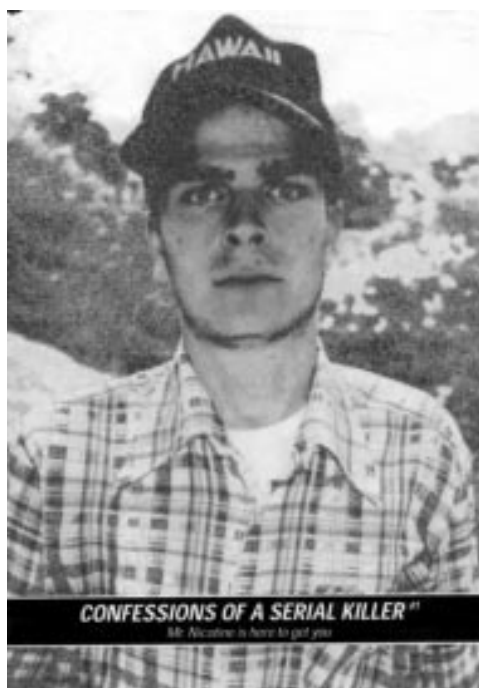
Whether we can rid the world of the cigarette as we have of smallpox remains a question, but there is no doubt the product can be cleaned up. Whether nicotine addiction disappears in 50 years is less important than whether the delivery systems have been improved. I am not prepared to pontificate on whether nicotine addiction, fed by less toxic delivery systems, needs to be treated as a public health evil on the basis of today's evidence, but it is certainly a public health evil while cigarettes are the major delivery system.

Is this a plea for prohibition? No—for evolution, and for a regulatory approach to the cigarette similar to that taken with other nicotine delivery systems and consumer products.

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- 1 Winstanley M, Woodward S, Walker N, eds. *Tobacco in Australia*. 1995:87–102.
- 2 Wynder EL, Graham EA, Croninger AG. Experimental production of carcinoma with cigarette tar. *Cancer Res* 1953;13:855–64.
- 3 Wynder EL, Kopf P, Zeigler H. A study of tobacco carcinogenesis. II. Dose response studies. *Cancer* 1957;10:1193–200.
- 4 Gray N, ed. *Lung cancer prevention; guidelines for smoking control*. Geneva: Union Internationale Contre le Cancer, 1977.
- 5 International Agency for Research on Cancer. *Monographs on the evaluation of the carcinogenic risk of chemicals to humans—tobacco smoking*. Lyon: International Agency for Research on Cancer, 1986;38:217–20.
- 6 Dean G, Lee PN, Todd GF, et al. Report on a second retrospective study in northeast England. Part 1. Factors related to mortality from lung cancer, bronchitis, heart disease, and stroke in Cleveland County with particular emphasis on the relative risks associated with smoking filter and plain cigarettes. (Research Paper 14) London: Tobacco Research Council, 1977.
- 7 Hawthorne VM, Fry JS. Smoking and health. The association between smoking behaviour, total mortality and cardiorespiratory disease in west Scotland. *J Epidemiol Commun Health* 1978;32:260–6.
- 8 Lubin LH. Modifying risk of developing lung cancer by changing habits of cigarette smoking. *BMJ* 1984;289:1953–6.
- 9 Rimington J. The effects of filters on the incidence of lung cancer in cigarette smokers. *Environ Res* 1981;24:162–6.
- 10 Wynder EL, Mabuchi K, Beattie EJ jr. The epidemiology of lung cancer: recent trends. *JAMA* 1970;213:2221–8.
- 11 Bross ID, Gibson R. Risk of lung cancer in smokers who switch to filter cigarettes. *Am J Public Health* 1968;58:1396–403.
- 12 International Agency for Research on Cancer. *Monographs on the evaluation of the carcinogenic risk of chemicals to humans—tobacco smoking*. Lyon: IARC, 1986;38:111–4.
- 13 Wynder EL, Stellman SD. The impact of long term filter usage on lung and larynx cancer risk: a case control study. *J Natl Cancer Inst* 1979;62:471–7.
- 14 Hammond EC, Garfinkel L, Seidman H, et al. ‘Tar’ and nicotine content of cigarette smoke in relation to death rates. *Environ Res* 1976;12:263–74.
- 15 Tang JL, Morris JK, Wald NJ, et al. Mortality in relation to tar yield of cigarettes: a prospective study of four cohorts. *BMJ* 1995;311:1530–3.
- 16 Peto R. Influence of dose and duration of smoking on lung cancer rates. In: Zaridze DG, Peto R, eds. *Smoking: an international problem*. Lyon: International Agency for Research on Cancer, 1986.
- 17 Waller RE, Froggatt P. Product modification. *Br Med Bull* 1996;52:193–205.

- 18 Dunn P. *Report of Canada's expert committee on cigarette modifications*. Ottawa: Health Canada, 1996:21.
- 19 Russell MA. Cigarette dependence. I. Nature and classification. *BMJ* 1971;2:330-1.
- 20 Russell MA, Wilson C, Patel UA, et al. Plasma nicotine levels after smoking cigarettes with high, medium, and low nicotine yields. *BMJ* 1975;2:414-6.
- 21 Benowitz NL, Hall SM, Herning RI, et al. Smokers of low-yield cigarettes do not consume less nicotine. *N Engl J Med* 1983;309:139-42.
- 22 Russell MA. Low-tar medium-nicotine cigarettes: a new approach to safer smoking. *BMJ* 1976;1:1430-3.
- 23 Hoffmann D, Hoffmann I. The changing cigarette, 1950-1995. *J Toxicol Environ Health* 1997;50:307-64.
- 24 Fischer S, Spiegelhalter B, Preussmann R. Tobacco specific nitrosamines in commercial cigarettes: possibilities for reducing exposure. In: O'Neill IK, Chen J, Bartsch H, eds. *Relevance to human cancer of N-nitroso compounds, tobacco smoke and mycotoxins*. Lyon: International Agency for Research on Cancer, 1991:489-92.
- 25 Fischer S, Spiegelhalter B, Preussmann R. Tobacco specific nitrosamines in mainstream smoke of West German cigarettes—tar alone is not a sufficient index for the carcinogenic potential of cigarette smoke. *Carcinogenesis* 1989;10:169-73.
- 26 Cox JD, Resner RA. Adenocarcinoma of the lung: recent results from the Veterans Administration lung group. *Am Rev Respir Dis* 1979;120:1025-9.
- 27 Vincent RG, Pickren JW, Lane WW, et al. The changing histopathology of lung cancer. *Cancer* 1977;39:1647-55.
- 28 El-Torkey M, El-Zeky F, Hall JC. Significant changes in the distribution of histological types of lung cancer: a review of 4928 cases. *Cancer* 1990;65:2361-7.
- 29 Johnson WW. Histologic and cytologic patterns of lung cancer in 2580 men and women over a 15-year period. *Acta Cytol* 1988;32:163-8.
- 30 Beard MC, Anneges JF, Woolner LB, et al. Bronchiogenic carcinoma in Olmsted County, 1635-1979. *Cancer* 1985;55:2026-30.
- 31 Cutler SJ, Young JL. Third national cancer survey: incidence data. *J Natl Cancer Inst Monogr* 1975;41:1-454.
- 32 Young JL, Percy CL, Asire AJ, eds. Cancer incidence and mortality in the United States, 1973-1977. *National Cancer Institute Monograph* 1981;57:1-1082.
- 33 Devesa SS, Shaw GL, Blot WJ. Changing patterns of cancer incidence by histologic type. *Cancer Epidemiol Biomarkers Prev* 1991;1:29-34.
- 34 Wu AH, Hendersom BE, Thomas DC, et al. Secular trends in histologic type of lung cancer. *J Natl Cancer Inst* 1986;77:53-6.
- 35 Thun MJ, Lally CA, Flannery JT, et al. Cigarette smoking and changes in the histopathology of lung cancer. *J Natl Cancer Inst* 1997;89:1580-6.
- 36 Wynder EL, Hoffmann D. Smoking and lung cancer: scientific challenges and opportunities. *Cancer Res* 1994;54:5284-95.
- 37 US Department of Health and Human Services. *Changes in cigarette related disease risk and their implication for prevention and control*. Rockville, Maryland: US Department of Health and Human Services, Public Health Service, National Cancer Institute, 1997;305-33. (NIH Publication No. 97-4213.)
- 38 Bates C, Connelly GN, Jarvis M, eds. *Tobacco additives—cigarette engineering and nicotine addiction*. London: Action on Smoking and Health, 1999:1-15.
- 39 Boyle P. European cancer experts recommendations for tobacco control. *Ann Oncol* 1997;8:9-13.
- 40 DeNoble VJ. In: Bates C, Connelly GN, Jarvis M, eds. *Tobacco additives—cigarette engineering and nicotine addiction*. London: Action on Smoking and Health, 1999:16.
- 41 Gray N, Boyle P, Zatonski W. Tar content in cigarettes and carcinogen content. *Lancet* 1998;352:787-8.
- 42 Henningfield JE, Benowitz NL, Slade J, et al. From the American Medical Association—reducing the addictiveness of cigarettes. *Tobacco Control* 1998;7:281-93.
- 43 Benowitz NL, Jacob P 3rd, Slade J, et al. Nicotine content of the eclipse nicotine delivery device. *Am J Public Health* 1997;87:1865-6.



The Cancer Society of Finland launched a new anti-tobacco campaign for teenagers and young adults recently. The theme of the campaign is "Serial killer" and is built around a dedicated internet site (www.serialkiller.fi) designed like a police report file. On the web site teenagers are challenged to create their own anti-smoking video (examples are shown) or other material as a competition. The web site is advertised with postcards, posters, and mysterious looking "missing" ads.